Amendments to the Specification:

Please amend the specification as follows:

Please replace paragraph 62 with the following:

[0062] A schematic representation of an optical reflectometer metrology tool 200 that depicts one embodiment of the present invention is presented in Figure 2. As is evident, the source 210, beam conditioning module 220, optics (not shown), spectrometer 230 and detector 240 are contained within an environmentally controlled instrument chamber 202. The sample 250, additional optics 260, motorized stage 270 (which may include an optional desorber) are housed in a separate environmentally controlled sample chamber 204 so as to enable the loading and unloading of samples without contaminating the quality of the instrument chamber environment. The instrument and sample chambers are connected via a controllable coupling mechanism 206 which can permit the transfer of photons, and if so desired the exchange of gases to occur. For example, coupling mechanism 206 may be optical windows, may be gate valves which open when an optical transmission path is desired, or may be other mechanisms that suitably allow an optical path to be coupled between the two chambers. In this manner an optical path between the instrument and sample chambers is provided. Additionally a processor 290 located outside the controlled environment may be used to analyze the measured data. It will be recognized that processor 290 may be any of a wide variety of computing means that may provide suitable data processing and/or storage of the data collected.

Please replace paragraph 67 with the following:

[0067] A more detailed diagram of one embodiment of an optical reflectometer metrology tool 500 is provided in Figure 5, wherein the optics comprising the measurement and reference channels of the device are illustrated in more detail. Though not shown, it will be recognized that the optical reflectometer metrology tool may include the components shown in Figure 2 such as the purge or vacuum system 280, processor 290, stage 270, etc. As shown in Figure 5, a

source 510, spectrometer 530, and array detector 540 may be provided in an instrumentation chamber 502. A sample chamber 504 is coupled to the instrumentation chamber 502 ~~504~~ through coupling mechanisms (not shown).

Please replace paragraph 69 with the following:

[0069] In one embodiment, the mirror 1, mirror 2, mirror 3 and mirror 4 are off-axis parabolic reflectors; an example of such is depicted as off-axis mirror 600 in Figure 6. These mirrors are preferably polished using conventional techniques following their manufacture and then covered with some form of broad band reflective coating 610 like Al/MgF$_2$ (some ~~manufactures~~ manufacturers may implement aluminum and MgF$_2$ layers directly on each other on the mirror or alternatively thin layers of other materials may be located under or over the aluminum layer). Post polishing improves the imaging properties of the mirrors by minimizing issues arising from diamond turning artifacts. The broad band coating 610 is tailored to enhance the reflective properties of the mirrors in the VUV. Examples of particularly well-suited coatings for coating 610 are produced by Acton Research Company. Figure 7 illustrates reflectance plots for coating #1000, #1200, and #1600 produced by Acton Research Corporation (plots 700, 710 and 720 respectively). For operation at shorter wavelengths other coatings like elemental iridium may be better suited.

Please replace paragraph 74 with the following:

[0074] Referring again to Figure 5, once the light enters the spectrometer 530 it is ~~is it~~ reflected by a plane mirror 531, collimated by a focusing mirror 532 and incident upon a diffraction grating 533. Some portion of the light diffracted by the grating is collected by the second focusing mirror 534 and focused onto the surface of the VUV sensitive array detector 540. As is known in the art, the light that is reflected from the diffraction grating becomes spatially separated by wavelength across the width of the detector. It is noted that in this particular embodiment all of the optics inside the spectrometer have also been coated with broad band reflective coatings like Al/MgF$_2$ to increase their efficiencies. Ideally, the spectrometer is an

imaging spectrometer that is designed in such a manner as to provide stigmatic imaging in a large area flat field as is the case with the 250 is/sm manufactured by Chromex Instruments (see also U.S. Patent No. 4932768). Such spectrometers typically allow a wide range of multiple wavelengths to exit the spectrometer simultaneously for detection by the detector element (as opposed to some types of spectrometers which attempt to restrict the exiting light to a single wavelength). Typically, such spectrometers utilize a fixed diffraction grating since a moveable diffraction grating is not required to generate the data at varying wavelengths. The imaging spectrometer may be utilized in combination with an array detector such that the multiple wavelengths exiting the spectrometer may be spread across the width of the array detector. The columns across the width of the detector are thus presented with light of different wavelengths. The internal elements of imaging spectrometers may be designed such that the multiple wavelengths are sufficiently resolved so that the array detector may accurately obtain data for various wavelengths.

Please replace paragraph 77 with the following:

[0077] Another aspect of the array detector 540 is that it may be cooled to low temperatures (below 0° C) to reduce dark counts (i.e. thermally generated carriers) which mask a̲ a̶s̶ measured signal and can adversely affect system accuracy in cases where low photon levels prevail. In order to cool the detector, it may be necessary to encapsulate it in a hermetically sealed chamber to prevent condensable species from accumulating on the device. This is usually accomplished by mounting the device in a vacuum chamber sealed with an MgF_2 window to permit VUV photons to pass. For operation at shorter wavelengths (generally below about 115 nm, the transmission cutoff for MgF2) the protective window could be removed as the controlled environment would be that of vacuum, rather than a non-absorbing purge gas. A particularly well-suited detector (Model # DV-420-BN) is manufactured by Andor Technology of Northern Ireland. This particular detector is an array detector that has a width of 26.6 mm and a height of 6.7 mm. Such a detector is formed of an array of pixels arranged as rows and columns. In this example a typical pixel may be 26 microns in width and height, though detectors with smaller resolutions on the order of 10 microns are also typically available.

Please replace paragraph 78 with the following:

[0078] To aid in the selection of discrete measurement locations on patterned samples an optional camera system 565 (i.e. camera plus necessary focusing elements) could be employed. While there are numerous ways in which to integrate such a system into the reflectometer arrangement, one possible method is to use it to capture the beam passing through the sample channel 508 and reflecting from ~~of~~ Beam Splitter 2. When utilized in this manner, the camera system 565 could be used to collect images at any time the sample channel 508 is in use (i.e. when Shutter 1 is open). Alternatively, a flip-in mirror could be added to the camera system to temporarily redirect some portion of the sample beam (following reflection from the sample) to the camera. Finally, there is also the option of introducing separate illumination and/or collection optics to the reflectometer in order to acquire images and locate specific features on the sample.

Please replace paragraph 83 with the following:

[0083] The systems and techniques described herein are particularly ~~particular~~ advantageous for use in applications where a high speed measurement is desirable. In addition to the capability of obtaining data from a number of discrete locations within a given localized region, these measurements may be obtained without the need for slow step and scan techniques that utilize movable diffraction gratings.

Please replace paragraph 89 with the following:

[0089] The benefit of these reference configurations can be described as follows. As the attenuation of VUV photons due to absorbing atmospheric species is a function of optical path length (the longer the path, the more absorbing molecules encountered), and as the dependence is non-linear in nature, it follows that the sample and reference arms should be substantially of the same length if similar attenuation effects are to be encountered by each beam. If this is not the case, and the arms are of different lengths, then data taken at any time following a calibration

measurement will only be accurate if the concentration of absorbing species in the environment is precisely identical to that present when the calibration measurement was performed. As this condition is virtually impossible to ensure it ~~in~~ remains highly improbable that accurate results can be obtained unless the sample and reference path lengths are equal.

Please replace paragraph 92 with the following:

[0092] In yet another embodiment of the invention virtually all of the optical elements, with the exception of the sample itself, are housed within the instrument chamber. This configuration, illustrated in Figure 11, significantly reduces the spatial requirements of the sample chamber, rendering it well suited to integrated process control applications. As shown in Figure 11, an optical reflectometer metrology tool 1100 is provided. A source 1110, spectrometer 1170, and array detector 1180 are provided within an instrument chamber 1102. Also provided within the instrument chamber are all of the optical elements of both the sample beam path and the reference path. Thus, mirrors 1-6, and shutters 1-3 are all located within the instrument chamber 1102. Mirror 2 focuses the beam down (into the plane of the figure) through a coupling mechanism 1106 into the sample chamber 1104. From the sample 1150, the sample beam then travels up (out of the plane of the figure) through the coupling mechanism to mirror 3. As shown in Figure 11, the reference beam path passes through two coupling mechanisms <u>1105A</u> ~~1105~~ (such as windows or gate valves) that couple the reference beam from the instrument chamber 1102 into the sample chamber 1104 and back into the instrument chamber 1102. In this manner the reference beam is subjected to the environment of the sample chamber just as the sample beam is. Ideally, the distance that the reference beam travels in the sample chamber 1104 will match the distance that the sample beam travels in the sample chamber. Further, it will be noted that the reference beam passes through a coupler mechanism twice just as the sample beam does. Thus, the optical path of the reference beam is designed to closely simulate the conditions of the sample beam. In this manner, the optical paths of the reference beam and the sample beam are similar both overall and with regard to the individual paths in the instrument chamber and the sample chamber. It will be recognized that the path and arrangement of coupling mechanism

shown in Figure 11 is exemplary and other paths and arrangements may be utilized while still achieving the benefits described herein.

Please replace paragraph 96 with the following:

[0096] With the arrangements of Figures 11, 11a and 11b, the optical path length within the sample chamber can be quite short, relative to that enclosed within the instrument chamber. In a preferred embodiment the optical path in the sample chamber could be short within the range of microns. Alternatively, to ease design of the process tool the path could be much longer in the range of hundreds of centimeters. The longer the optical path, however, the more desirable it is to minimize the presence of absorbing features and thus increase increases the environmental demands placed upon the sample chamber. If a short optical path is utilized, the requirements on the quality of the sample chamber environment are reduced, thereby reducing settling times and increasing sample throughput. A further benefit arises as optical surfaces housed within the continuously maintained instrument chamber are less susceptible to contamination than if they were resident in the cyclic environment of the sample chamber. While not explicitly denoted in Figure 11, it is implied that the optical path lengths of the reference and sample beams are near identical either through judicious design of the sample chamber itself or by some other means of adjustment or positioning of the sample, or one or more of the coupling mechanisms between the sample and instrument chambers. Figures 11, 11a, and 11b illustrate the use of a sample chamber of reduced size. It will again be recognized that other features and elements of the systems of Figures 2, 5, 11, 11a, and/or 11b may be interchanged with each other even though all of such features or elements are not illustrated within the figures. Thus, for example an optical reflectometer metrology tool of Figure 11 may utilize camera, a purge or vacuum system, a processor, a Michelson interferometer design, etc. and it will be recognized that the system shown in any particular figure is not limited to use with only those elements illustrated or the arrangement of the elements as shown.

Please replace paragraph 100 with the following:

[00100] While different applications can sustain different degrees of inaccuracy, it is likely that in many applications one would generally prefer to keep such errors less than 0.1% and in some cases below 0.01% or less. The range of concentration differences that could be encountered would depend to a large extent on how the instrument was designed and employed. For example, stand alone systems may be designed for use with adequate purge and/or vacuum control such that it is likely that concentration differences could <u>be</u> maintained at very low levels (on the single digit PPM level), whereas in integrated applications where the metrology instrument is attached to other process tools such as described with reference to Figure 11b (and hence some fraction of the sample chamber resides within that other process tool), it may not be possible to control the differences.

Please replace paragraph 110 with the following:

[00110] A more detailed example of the typical steps involved in a calibration, referencing and measurement sequence 1200 are provided in the flowchart of Figure 12a. As indicated by step 1205, a calibration sample with a known reflectance may be loaded into a location for measurement (such as within a sample chamber) and then purging and/or vacuum pumping may occur to establish suitably low environmental concentrations of absorbing species. An optical reflectometer measurement may then be obtained from the calibration sample to record an intensity of the calibration sample as indicated by step 1210. Such data may be saved by the processor or other computing system. Next a source intensity profile may be calculated as indicated by step 1215. Step 1220 includes recording the intensity of the reference channel at a time t_1. Utilizing the prior recorded and calculated data, a reference reflectance may then be calculated as shown in step <u>1225</u> ~~1125~~.

Please replace paragraph 112 with the following:

[00112] Additional measurements may then be performed on the same unknown sample or another unknown sample. It will be recognized that for such additional references another loading and measurement of a calibration sample may not occur for each of such measurements, but rather, the calibration data may be stored for re-use and only the referencing and unknown sample steps need be performed again. In yet another embodiment, the data of the referencing steps may also be reused such that additional referencing is not performed for every additional unknown sample measurement. Thus, it will be recognized that the referencing techniques described herein may be utilized in a wide variety of manners while still obtaining at least some of the benefits of the referencing techniques.

Please replace paragraph 117 with the following:

[00117] The concepts disclosed herein provide a VUV optical reflectometer metrology tool. The design of the tool is simple and robust rendering it easy to operate at VUV wavelengths. Further, the tool avoids many of the problems associated with ellipsometry techniques. For example, the tool and techniques disclosed herein may be utilized without polarization elements. In ellipsometry, the change in the polarization state of light reflected from the surface of a sample is measured. Typical ellipsometry techniques incorporate use at least two polarizing elements (one in the optical path prior to the sample and one in the optical path after the sample). Such techniques are time consuming because of the nature of collecting data for multiple polarization angles. In addition, polarization elements are generally absorbing thus making them unsuitable for low wavelength measurements, particularly in the VUV regions of about 140 nm or less. Thus, the systems and techniques described herein (which may be utilized without polarizing elements) are particularly advantageous for use with wavelengths that are low end VUV regions (or lower). The absorbing nature of polarizing elements also increases the time necessary to collect sufficient light to obtain a measurement.

Please replace paragraph 130 with the following:

[00130] Further evidence of the benefit of such a dynamic weighting function is provided in Figure 25, which also presents reflectance spectra from three $SiO_2/SiN/Si$ samples. In this case the SiN layer thickness is fixed at 1000Å ~~1000Å~~ amongst the samples, while the SiO_2 layer thickness varies from 0 Å (plot 2510), to 10 Å (plot 2520) to 20 Å (plot 2530). As is seen, the spectra exhibit clear differences in the VUV region, while appearing virtually identical in the DUV. Thus, because of the sensitivity of the tools and techniques described herein to absorption effects, the absorption of shorter wavelengths in the thin films being measured may be advantageously utilized. Moreover, in situations in which a rough estimate of the anticipated sample characteristics is known (for example a rough estimate of the underlying SiN film thickness), greater importance (or dynamic weighting) may be placed upon the reflectivity data in certain wavelength regions.

Please replace paragraph 138 with the following:

[00138] Figure 30 illustrates how the VUV techniques and apparatus described herein can be used to measure or monitor changes in the height of lines comprising a line array. Two curves are presented in the figure. The first curve 3010, corresponding to the y-axis on the left hand side, presents the expected reflectance signal from a line array with 65 nm lines and spaces, wherein the line height is 1000 Å. The second curve 3020, corresponding to the y-axis on the right hand side, presents the difference signal associated with a 10 Å [[A]] increase in line height for the same such line array. As is evident the changes in line height bring about a spectral signature markedly distinct from the changes introduced through in line width and pitch presented earlier (for reference refer to Figure 29 and Figure 30). That is, the spectral region exhibiting the smallest difference signal resulting from changes in line height is in fact the same spectral region exhibiting the largest difference signal resulting from changes in line width and pitch.